**The impact of human spaceflight on young people’s attitudes to STEM subjects**

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**Abstract**

*Background*

The work forms part of a study conducted in the UK at the time of the *Principia* Mission, in which the British astronaut, Tim Peake, went to the International Space Station.

*Purpose*

This paper describes the development and use of an on-line instrument to measure young people’s attitudes to STEM subjects and to human spaceflight.

*Sample*

555 primary students and 796 secondary students completed all three surveys. Students were aged 9 and 12 at the first data collection point.

*Design and methods*

The study as a whole was a three-year, mixed-methods study combining a large-scale survey of attitudes to STEM subjects and to human spaceflight with interviews with participating students and staff. This paper reports the survey data. Data were gathered at three points: prior to the *Principia* Mission, shortly after, and approximately one year later.

*Results*

Students were positive about the value of STEM subjects, and about space science. Paired t-tests showed few significant differences in the pre- and post-surveys. There was a downward trend from primary to secondary age groups in relation to considering careers in STEM subjects and in space science. Primary students retained more interest in STEM subjects and showed increased interest in aspects of space science than secondary students. Boys were more positive about space than girls, and more likely to see themselves working in STEM areas or space science.

*Conclusion*

The study suggests that spaceflight as a context stimulates immediate situational interest in students, but not longer-term interest. Thus, there does not appear to be a case for substantially increasing coverage of space science in the school curriculum. However, the findings point to the desirability of including more information about careers, including careers in space science, in STEM lessons.

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**Background, context and study aims**

Spaceflight has a fascination for many people, and there is evidence, much of it anecdotal, to suggest that space and space travel increase the interest of young people in science, technology, engineering and mathematics (STEM) subjects. This suggestion comes from groups including people who work in space science and related areas, including Government bodies, those involved in developing formal and informal activities related to learning about space science and spaceflight, such as university science departments, museums and other visitor attractions, and classroom teachers with a particular interest in space and space travel. Much of the published work comes from the United States (e.g. Fraknoi, 2007). However, little systematic empirical evidence has been collected to assess the strength of claims made about interest in space travel and uptake of STEM subjects.

The study reported here used the opportunity provided by the *Principia* mission in 2015-6 to test systematically the hypothesis that spaceflight and space travel have a positive impact on young people’s perception and uptake of STEM subjects. The *Principia* mission saw the British astronaut, Tim Peake, go to the International Space Station, and had, as a specific educational objective, engage young people with space science and with STEM subjects more widely. The UK Space Agency was heavily involved with the *Principia* mission, and wished to gather data on its impact on young people.

More broadly, the desire to increase the interest of young people in STEM subjects beyond the period of compulsory study has been the focus of considerable attention and longstanding concern in a number of countries. This is linked to concerns over shortages of people electing to pursue careers in STEM-related areas, with a consequent detrimental effect on a country’s economic effectiveness and competitive strength if there is a shortage of people with STEM skills and competencies. Within this, the ‘pool’ from which future STEM specialists are likely to emerge is seen to be restricted, with a lack of diversity in gender and social and ethnic background and a notable under-representation of women. Thus, exploring the impact of interventions aimed at improving young people’s attitudes to STEM subjects is particularly important.

***Aims of the study***

The study took the form of a large-scale, mixed-methods study. This paper reports on two of the study aims:

1. to design an online survey instrument to gather information on young people’s attitudes to STEM subjects, including attitudes to human spaceflight;
2. to use the survey instrument to gather longitudinal data over a three-year period to track the attitudes to STEM subjects of two cohorts of young people, one in primary schools and one in secondary schools.

Additional aims related to gathering interview data from teachers, students and key informants working in the space sector. The interview data are reported elsewhere. (Bennett, Airey, Dunlop and Turkenburg, 2018).

**Attitudes to STEM subjects and to space science: from the literature**

Students’ attitudes are seen as key determinants of levels of engagement and subject choice beyond the period of compulsory study. In science and mathematics, there are widespread and longstanding concerns in many countries over the numbers of students taking the subjects once they have a choice. It is therefore unsurprising that a considerable amount of effort has been expended to try and establish the underlying reasons, and this has resulted in an extensive literature on attitudes to STEM subjects, and particularly to science and to mathematics.

In a review of work in the area, Bennett, Braund and Sharpe (2014) identified a range of systemic factors, school factors, individual factors and external factors that shape attitudes to STEM subjects. These include the nature of the curricula, links with everyday life and the world of work, perceptions of STEM subjects, student confidence with the subjects (self-efficacy), student ability, home background, ethnic background, socio-economic status, and participation in formal and informal STEM-related activities outside school.

The volume of literature on attitudes to science and mathematics is also accompanied by a number of articles noting issues with the research. Attention was first drawn to challenges in gathering data on attitudes to science in the major review articles of Gardner (1975) and Schibeci (1984). They identified problems of definition of key terms, poor instrument design and a lack of standardisation in instruments for assessing attitudes, making comparisons between studies and meta-analysis of findings problematic. Similar concerns have also been raised about the quality of instruments used to assess attitudes to mathematics (Zan *et al*., 2006 and Larsen, 2013). While more recent studies have clarified definitions of terms and improved instrument design, other matters, particularly the lack of standardisation in instruments and their use in replication studies, still remain a challenge in work in the area. Specifically, any new study on attitudes (including the one reported here) has to address the matter of whether to develop a new instrument or use an existing one. The literature indicates that new instruments are still routinely developed for new studies.

For the purposes of the study reported here, Oppenheim’s (1992) definition of attitudes has been adopted.

...... attitudes as normally being a state of readiness or predisposition to respond in a certain manner when confronted with certain stimuli ...... attitudes are reinforced by beliefs (the cognitive component), often attract string feelings (the emotional component) which may lead to particular behavioural intents (the action-tendency component). (Oppenheim, 1992, p175)

This study focuses on young people’s attitudes to STEM subjects, and the factors that may influence their choices. The literature below therefore concentrates on these aspects.

*Attitudes to STEM subjects*

A number of studies suggest that science is seen by students as important and something everyone should study at school (e.g. Cerini, Murray and Reiss, 2004; Jenkins and Nelson, 2005; Bennett and Hogarth, 2009; Hamlyn, Matthews and Shanahan, 2017). However, students appear to be generally less positive about their experiences of school science than they are about science, and many young people appear to see science as, in the words of Jenkins and Nelson (2005) “important, but not for me”, in other words, they see the value of science but do not aspire themselves to study science or work in scientific job and careers. (Osborne and Collins, 2001; Jenkins and Nelson, 2005; Bennett and Hogarth, 2009; Tytler and Osborne, 2012; OECD, 2016, Sjøberg and Schreiner, 2010; Archer *et al*. 2013). The Relevance of Science Education (ROSE) international study (Sjøberg and Schreiner, 2010) reports that school science, when compared with other subjects, is seen by many students as less interesting and not leading to exciting jobs and careers.

As with science, mathematics is seen by students as an important subject in the school curriculum, with, for example, almost three-quarters of students aged sixteen believing that mathematics is important and useful in everyday life (Blenkinsop, McCrone, Wade and Morris, 2006). Attitudes to school mathematics appear to be less positive, with Nardi and Steward (2003) noting the ‘quiet disaffection’ of many students at age 14 who, whilst recognising the value of a mathematics qualification and feeling obliged to participate, demonstrate little real engagement in lessons. A particularly noticeable feature of the research into attitudes to mathematics is the association between enjoyment of mathematics and feeling confident or having strong self-belief, in the subject (Matthews and Pepper, 2005; Kyriacou and Goulding, 2006; Brown *et al*., 2007; OECD, 2013).

Many students report finding science and mathematics difficult subjects that only a clever few can study, and this contributes to a disinclination to consider further study of the subjects or careers involving science and mathematics (Osborne and Collins, 2001; OCR Examination Board, 2005; Blenkinsop *et al*.,2006, Lyons and Quinn, 2010; Archer *et al*., 2013).

*Why students choose science and mathematics*

Students who choose to study science and mathematics subjects beyond the compulsory period report several reasons for doing so. Bennett, Lubben and Hampden-Thompson (2013) identified four categories of strategies that can influence subject choice: aspirational (linked to further study and/or career purposes), prior experience (subjects they have enjoyed, subjects where they have done well, teachers they liked, subjects with which they feel they have identified), or tactical (reducing risk, keeping options open, subjects that go well together), or external factors, such as parental and family effects. A number of other studies have confirmed the importance of students’ sense of identity and perceptions of their ability as playing a key role in subject choice (e.g. Munro and Elsom, 2000; Vidal Rodeiro, 2007; Tripne, Newman, Bangpan, Niza, MacKintosh and Sinclair, 2010; Archer *et al*. 2013). Lyons and Quinn (2010) found that around two-thirds of students choosing not to continue with science report difficulties in seeing themselves as scientists, and that school science had not opened their eyes to new and exciting careers. Mathews and Pepper (2005) reported similar responses to mathematics, although their work also identified a ‘clever core’ of students who see themselves as capable mathematicians for whom mathematics is not irrelevant or difficult, but an enjoyable subject which helps solve problems.

Archer *et al*. (2013) introduced the concept of ‘science capital’ as a key determining factor influencing young people when they make choices about subjects they pursue. Students who aspire to study science and STEM subjects are more likely to come from families where there is a high level of ‘science capital’ i.e. from socially advantaged backgrounds where they have a close family member or friend with STEM qualifications and working in STEM-related areas, and science-related leisure interests. This background helps to create a sense in young people that science is what people like them do, and that careers involving STEM subjects are realistic and attainable ambitions. Archer *at al.* (2013) further suggest that science capital explains why students who say that they like science do not want to study science subjects when they have a choice, or pursue careers in science: they do not have a sense that science is something they actually ‘do’.

*Career aspirations*

Studies of students’ career aspirations show that many young people have a firmly held view of what they want to do early in their secondary schooling. For example, the Institution of Mechanical Engineers (2010) report that 85% of students aged 11 already know what career they want to follow, and 65% have held this view for at least two years. Few of the careers cited by these students involve science or mathematics. Archer *et al*. (2013) report similar findings, noting that, in the context of science, 80% of students said they had decided careers in science were not for them before they had started secondary school.

*The nature of the curriculum and experiences in science and mathematics lessons*

Hampden-Thompson and Bennett (2011) analysed the PISA 2006 data for 12,000 students aged 15 in the UK to explore the effects of particular kinds of lesson activities on engagement in science. The students reported higher levels of engagement, future orientation and motivations towards science when they regularly experienced lessons characterised by interaction (students explaining their ideas, and expressing their opinions), hands-on activity (practical work, designing investigations) and an emphasis on the relevance and applications of what is being studied. The Wellcome Trust Science Tracker (Hamlyn et al., 2017) also identified practical work as having a positive influence on students’ decisions to study science subjects.

Experiences in mathematics lessons also influence engagement, and often have a negative impact on attitudes to mathematics (Nardi and Steward, 2003; Mathews and Pepper, 2005.) Students report that they are often applying techniques that they do not understand, even though they get the right answer, with much depending on repetition and rote learning. In contrast to science, there is also some evidence that students have negative attitudes to contextualised learning activities in mathematics, due to a mismatch of perceptions of relevance (Nardi and Steward, 2003; Kounine *et al*., 2008).

*Self-efficacy in relation to mathematics and science subjects*

Exploring links between self-efficacy and engagement and participation is a relatively new area of work in relation to science, though more established and extensive in relation to mathematics. Self-efficacy is concerned with the extent to which individuals believe they have the ability to perform specific tasks (Bandura, 1997). Students’ learning experiences play an important part in their notions of self-efficacy. Self-efficacy is seen as an important predictor of success with learning which, in turn, may be linked to increased levels of engagement.

PISA has looked at self-efficacy in science (OECD, 2016) and in mathematics (OECD, 2013), The findings indicate that self-efficacy is closely related to performance. Lyons and Quinn (2010) found self-efficacy to be an important influence on choice, particularly for girls, who have lower self-efficacy than boys and are particularly sensitive to anticipated difficulties. Similar findings have emerged from studies of confidence in mathematics (e.g. Wang, 2013), which have also pointed a link between self-efficacy and subject choice.

In summary, many young people recognise the importance of STEM subjects to society, but most do not see themselves studying these subjects beyond the compulsory period: by the age of 11-12, most students already see STEM subjects as something they personally are not going to study.

*Attitudes to space science and astronomy*

There is far less literature on attitudes to space science and astronomy. The bulk of the literature focuses on descriptions of educational resources and their use. Where there is a research focus, much of the work has been undertaken at university and college level. Some reviews of research in astronomy education have been undertaken (Bailey and Slater, 2004; Fraknoi and Wolff, 2007; Lelliott and Rollnick, 2010). The earlier work reports on misunderstandings about astronomy in university and college-level students (e.g. Zeilik, Schau & Mattern, 1998), and argues for more “theory-driven research in real classrooms” (Bailey and Slater, 2004, p38). The review of Lelliott and Rollnick (2010) focuses on research in elementary and high schools, and notes an increase in research publications. However, the principal focus remained on misunderstandings and aspects of conceptual development (around 80% of the 103 studies included in the review). Only four studies explored attitudes to astronomy.

Where data have been gathered on young people’s attitudes to space science and astronomy, it has often been part of a larger study exploring responses to science (e.g. Jarvis and Pell, 2002, 2005; Jenkins and Pell, 2006). The studies suggest a broadly positive response to space and human spaceflight. The two studies by Jarvis and Pell are of particular relevance to the work reported here as they involve a pre-test, post-test and delayed post-test design with students aged 110 and 11. In their earlier study in 2002, they found that around half of the students had more positive attitudes to science and space science immediately after their visit to the space centre, with 25% reporting increased interest in becoming a scientist. These effects were broadly maintained in the delayed post-test study, undertaken five months after the visit. However, the remaining 50% of students showed no change in attitudes or were more negatively disposed. The 2005 study was very similar to the earlier study but included more input from teachers to prepare students for the visit. In this study, 20% of students reported increased interest in becoming a scientist, with girls’ scores remining significantly higher in the five-month post-test. One outcome of such work has been the advocacy of space as a context to foster interest in science and other STEM subjects (e.g. Clements, Curtis, Jackson and Lyons, 2014).

**Overview of research design**

The study took the form of a longitudinal study, tracking two cohorts of students over three years during the period 2014-2018. One cohort comprised upper primary level students, aged nine at the start of the study, and the other lower secondary students, aged twelve at the start of the study. The data were gathered via a bespoke survey of students’ responses to STEM subjects and human spaceflight. Additional quantitative data from the UK National Pupil Database (NPD) allowed for the characterisation of each of the schools participating in the study.

Survey data were collected at three points in schools. Phase 1 data (baseline) and Phase 2 data (immediate follow-up) were gathered before and after Tim Peake’s mission to the International Space Station, i.e. September-December 2015 and March-July 2016 respectively. Phase 3 data (longer term follow-up) were gathered approximately one year after the immediate follow-up data in April-June 2017.

**Instrument design and validation[[1]](#footnote-2)**

The research literature into attitudes to STEM, rather than attitudes to the four component subjects, is sparse. In consequence there are very few examples of dedicated and fully validated instruments to gather data on attitudes to STEM subjects. Those that do exist, such as the S-STEM (Students Attitudes Towards STEM) surveys (Friday Institute for Educational Innovation, 2012a and 2012b; Unfried et al., 2015), were specifically developed for a US situation to evaluate the implementation of a fully integrated STEM curriculum. The focus of the S-STEM instrument did not lend itself to use or adaptation for the study described here, so a dedicated instrument was developed for the study.

A range of existing studies and instruments was consulted for the development of the attitudes to STEM instrument, including those specific to the four individual STEM subjects, and Space, the fifth aspect of the study, as shown in Table 1. The instruments were scrutinised for their overall structure and the focus and content of individual items, including search for items specifically relating to space science.

[Table 1 about here.]

Systematic scrutiny of existing instruments revealed several similar features in design and focus, including the use of Likert (agree/disagree) scales, and probes on level of interest in subjects, perceptions of difficulty, career aspirations, and responses to STEM disciplines within and beyond school.

It was not possible to identify any instruments focusing solely on attitudes to astronomy and spaceflight. However, several of the science instruments consulted contained relevant items, although this dimension was not explored as a separate strand within these instruments. Where appropriate, these items were incorporated or adapted into the research instrument developed for the study reported here.

The development of the instrument involved five steps:

1. Likert-type items were constructed to probe similar aspects for each of the STEM subjects, e.g. views of the subject in school, views of the subject outside school lessons, careers involving the subject, external influences from family/peers/teachers, confidence in and/or perception of difficulty of the subject.
2. Items were constructed for a specific strand on space/spaceflight/human spaceflight, following the same patterns as those for the STEM subjects as far as possible.
3. Two versions of the instrument were developed, one for each of the primary and secondary age ranges to take account of aspects such as curriculum experiences and levels of maturity.
4. The instrument was put into an on-line format using Google Forms.
5. The instrument was piloted and tested for reliability and validity before being finalised after minor modifications.

Additionally, demographic data, such as gender and age, were added at the start of the instrument, and a small number of open-ended questions were included in each section. These related to students’ personal experience of, and interest in, each of the subjects, together with their knowledge and experience of their school’s STEM-related clubs.

The sections in the instrument were ordered Science, Mathematics, Space, Technology and Engineering. This was to reflect the time students were likely to spend on each STEM subject in school, and to avoid losing data on space science through students running out of time towards the end of the questionnaire. In practice, almost all students completed the whole survey, possibly due to it being available on-line.

The areas probed were kept as similar as was feasible for primary and secondary age students. Consultation with teachers in the development and pilot phases resulted in two modifications. Firstly, the sections on Technology and Engineering for the secondary age range were combined into one section for the primary age range, called ‘Designing and making’. This provided a better match to the primary school curriculum. Secondly, the five-point Likert scale used with secondary students was reduced a three-point scale with primary age students to simplify the instrument for younger students.

The instrument was piloted in four secondary schools and five primary schools (158 and 91 students respectively), with a year group representing the same age group as the ones who would be completing the main survey in the following academic year.

Cronbach’s alpha calculations were used to give an indication of the internal data consistency and reliability of the items in the instrument, and showed these to be high. For the five individual subject sections (including space), Cronbach’s alpha ranged between 0.752 and 0.931 across the phases and the primary and secondary versions. Combining all the sections to check for reliability of the whole survey resulted in an increase of Cronbach’s alpha to >0.90. Removal of individual items did not result in improved consistency or reliability, as judged by Cronbach’s alpha and Principal Component Analysis techniques.

The final instrument contained 106 items for secondary students, and 86 items for primary students, plus twelve questions on demographic data.

**Identification of the sample and recruitment of schools**

Schools were recruited to the study in several ways. Agencies with a remit to promote space science activities sent out emails on behalf of the study, and schools applying to take part in certain *Principia-*related projects were similarly invited to join the study. In addition, the study was publicised through a range of email lists, and this resulted in people in several schools contacting the authors directly. Schools were also approached via the email addresses of STEM subject leaders on school websites.

To ensure the sample did not reflect a preponderance of schools already heavily engaged in, or committed to, activities related to the *Principia* mission, the UK National Pupil Database (NPD) was used to identify a range of school characteristics. These included school achievement in science, levels of STEM subject uptake, gender and ethnicity of students, socio-economic status of students’ families/carers, and measures of disadvantage/deprivation. This enabled the recruitment process to be expanded to include schools which had not been in contact with any of the science education or space-related projects. Schools were selected for approach by creating randomly generated batches from the full NPD list acquired.

The subset of case study schools was identified based on patterns of responses to the survey. Again, care was taken to reflect a broad range of schools and levels of interest in the *Principia* mission.

Tables 2 provides details of the sample.

[Table 2 about here.]

In total, 409 secondary boys, 374 secondary girls, 267 primary boys and 282 primary girls completed the instrument on all three occasions, and this sample was used for the data analysis.

**Data analysis methods**

The quantitative data from the survey instrument were subjected to t-tests to compare means of different groups of respondents over the duration of the study. This paper focuses on the data comparing primary and secondary students’ responses in each of the first and third phases of data collection.

**Findings**

The study gathered a substantial quantity of data on both primary and secondary students from the three surveys. As the study was interested in the long-term effects of looking at the influence of studying human spaceflight on interest in STEM subjects, the data reported in this paper focuses on the changes between Phase 1 and Phase 3.

Figures 1-4 show responses over the three phases to items on the attitude inventory. The data for the primary students represents the percentage of students agreeing with each of the statements. The data for secondary students represents the combined ‘agree’ and ‘strongly agree’ responses.

[Figures 1-4 about here.]

***Views of STEM subjects***

Around 40% of primary school students reported science as being one of their favourite lessons at Phase 1, declining to 30 % across the two years of the study. They were most positive about science making people’s lives better (over 70% of students at each phase of the study), and scientists having well-paid jobs. In Phase 1, around 40% reported talking to their parents about science, with this declining to 30% in Phase 3. Students’ confidence in their ability in science, and their expectations of using science in some form into the future were not matched by a desire to pursue a science career, with less than one-fifth of primary school students envisaging a career as a scientist. One response was statistically significant from Phase 1 to Phase 3, with fewer primary students having the view that *You need to be clever to be good at science* (t(413)=‑5.507, p=0.000).

Secondary students’ views were broadly similar to those of primary students. They were slightly more likely to believe that science improved people’s lives, to consider careers in science and to expect science to be part of their futures, though generally not as a career. They were also more likely than primary students to believe you need to be clever to study science, and this perception increased over the duration of the study. In contrast to primary students, there was a statistically significant increase in the belief that *You need to be clever to be good at science* (t(577)=7.354, p=0.000). These findings, particularly on the need to be clever and the mismatch between science being important, but not to the points of wanting to study science subjects, are very much in keeping with those of other studies on responses to science and school science (e.g. Bennett and Hogarth, 2009; Jenkins and Nelson, 2005;, the ASPIRES project, Archer and DeWitt, 2017; the ROSE project, Sjøberg & Schreiner, 2010; and the Wellcome Tracker, Hamlyn et al., 2017.

Mathematics was viewed more positively than science by primary students, with over half of the students being confident they were good at mathematics, compared to around 40% agreeing they were good at science. Over the duration of the study, there was a significant increase in the numbers agreeing with the statement *People who are good at maths get well-paid jobs* (t(411)=3.391, p=0.001).

The proportion of secondary school students agreeing that they could see themselves using mathematics in their jobs and to help them solve everyday problems was high, with 60-70% agreeing in each phase of data collection. Nonetheless, interest in learning mathematics decreased over the study. There was a significant increase in students believing that *You need to be clever to be good at maths* (t(573)=5.919, p=0.000). Maths was seen as more demanding than science and contributing less to making people’s lives better. Again, these findings are in keeping with other studies of responses to mathematics (e.g. Brown and Tibby, 2008).

Primary students’ expectations of using technology in their future jobs were higher than that for the other STEM subjects. Primary students became significantly more positive in their responses to *I am interested in using the latest technology* (t(394)=2.781, p=0.006). Over 60% of primary and secondary students viewed technology as making people’s lives better.

Secondary students showed similar levels of enthusiasm for technology as primary students but became less positive over the study. Despite this, they were interested in the idea of a career in which technology is used, or even where technology plays a large role.

The picture for engineering is similar to that for technology, although the secondary school students’ levels of agreement tended to be lower than those of primary students for most items. It is likely that students were less familiar with what is involved with engineering, as it is not a subject on the school curriculum. As with science and maths, the need to be clever was reported, with a significant increase in the response of secondary students to the statement *You can study engineering only if you are good at maths and science* (t(517)=2.084, p=0.038).

The data also showed that there was a notable decline in the primary students’ enthusiasm for school science and technology lessons in the final year of primary schooling. This may well be linked to much of this year being spent preparing for national statutory tests in English and Mathematics.

***Views of space and space science***

Figure 5 shows responses over the three phases to selected items on the attitude inventory.

[Figure 5 about here.]

Space science and space technology were viewed very positively – more positively than STEM subjects at Phase 1. For example, throughout the study, over half the primary and secondary students reported that they enjoyed learning about space in schools. Although views remained largely positive over the duration of the study, there were statistically significant decreases for both primary and secondary students in their responses to the statement *I enjoy learning about space in school lessons* (primary: t(411)=-7.392, p=0.000; secondary: t(569)=-3.887, p=0.000). In a similar vein, over 50% of primary and secondary students responded positively to the statement *When I learn about space, I am more interested in science*, but with a statistically significant decrease from Phase 1 to Phase 3 (primary: t(412)=-3.891, p=0.000; secondary: t(570)=-2.499, p=0.013).

Over 50% of students also reported that they enjoyed finding out about space more generally, and felt that it was important to send people into space. There were statistically significant decreases in responses to *I am interested in the technology which is needed for spaceflight* (t(410)=-5.740, p=0.000; secondary: t(558)=4.814, p=0.000). Only around a quarter of students responded positively to *I would like to have a job related to space science or space technology* and, for primary students, there was a significant decrease in responses from Phase 1 to Phase 3 (t(411)=-2.887, p=0.004). Both cohorts reported strong interest in learning about the human aspects of space exploration.

The need to be clever to have a career in space science was more pronounced than for any of the STEM subjects, with space science being perceived as even more difficult than maths. Both cohorts held negative views overall of careers in the space sector, and there was little change in views over the course of the study.

Overall, views of space science are less positive at secondary level than at primary level. A noticeable trend within the data was the appreciable differences in the responses of boys and girls, with these becoming more apparent at secondary level.

In Phase 1, there were no significant differences between primary boys and girls in responses to *I enjoy learning about space in school science*. By Phase 3, girls were significantly less positive than boys (t(416)=2.760, p=0.006). At secondary level, girls were less positive than boys in both phases (Phase 1: t(581)=3.189, p=0.000; Phase 2; t(573)=4.361, p=0.000). A similar pattern was seen for *When I learn about space, I am more interested in science* (Primary Phase 3: t(417)=2.587, p=0.010; secondary Phase 1: t(580)=2.738, p=0.006; secondary Phase 3: t(575)=5.060, p=0.000), and *I enjoy finding out about space* (Primary Phase 3: t(411)=3.363, p=0.001; secondary Phase 1: t(582)=3.511, p=0.000; secondary Phase 3: t(564)=3.516, p=0.000),

There was considerable interest from both boys and girls, particularly at primary level, in finding out about what happens to humans in space. However, at secondary level, girls became significantly less positive than boys (Phase 1: t(583)=3.003, p=0.003; Phase 3: t(554)=3.984, p=0.000). The decline of interest in space science from primary to secondary level, with girls becoming increasingly less positive than boys, reflects the overall pattern in the data for STEM subjects.

Although careers in space science were not viewed particularly positively by either boys or girls although, boys in both phases were significantly more likely than girls to express an interest in working in space-related jobs (Primary Phase 1: t(412)=3.843, p=0.000; primary Phase 3: t(416)=3.435, p=0.001; secondary Phase 1: t(582)=6.323, p=0.000; secondary Phase 3: t(572)=7.252, p=0.000). This reflects the pattern for science. For careers in maths, technology and engineering, gender differences were apparent at secondary level, but not at primary level.

With the exception of secondary students at Phase 3, boys were significantly more likely than girls to agree that *You to be clever to do a job in space science or space technology* (Primary Phase 1: t(412)=2.235, p=0.026; primary Phase 3: t(416)=4.297, p=0.000; secondary Phase 1: t(563)=4.118, p=0.000). Gender differences in responses to space science are not widely reported elsewhere, but this may well be due to the small number of detailed studies in the area.

**Conclusions**

This study set out to develop and use an instrument to measure students’ attitudes to STEM subjects and to space science. The instrument subsequently developed performed well and generated data that were both reliable and valid.

Using the instrument with two cohorts of students, one of primary age and one of secondary age, yielded data that indicated students’ attitudes to STEM subjects were largely positive overall. Students reported feeling generally positively-disposed towards learning about STEM subjects, both inside and outside school, and they valued what they saw as the important contribution the subjects made to people’s everyday lives and to society more widely. Indeed, views of the positive influence of science and technology on people’s everyday lives were among the most positive across the whole survey. These findings are in keeping with those of other studies (e.g. Jenkins and Nelson, 2005; Bennett and Hogarth, 2009; Tytler and Osborne, 2012; OECD, 2016, Sjøberg and Schreiner, 2010; Archer *et al*. 2013). Views of mathematics reflected were also largely positive, though students were less certain of the value of mathematics to society. Rather, they had a more personal, utilitarian view of mathematics, seeing it as a subject that was likely to be useful to them in their future jobs. This reflects the findings of other studies (e.g. Nardi and Stewart, 2003; Matthews and Pepper, 2005; Blenkinsop *et al*., 2006; Brown and Tibby, 2008).

As with other studies, the importance students attributed to the contribution of STEM subjects to everyday life was not reflected in their personal aspirations, with around three-quarters – indicating they were not planning to pursue a career in which one or more STEM subjects played an important role. Careers in technology generated a neutral response, careers in science and engineering were consistently viewed negatively, while those with an emphasis on mathematics were seen as the least desirable of all the STEM options. These findings reflect those of a number of other studies, including those of Bennett and Hogarth (2009), Brown and Tibby (2008), Jenkins and Nelson (2005), the ASPIRES project (Archer and DeWitt, 2017), the PISA 2015 data (OECD, 2016), the ROSE project (Sjøberg & Schreiner, 2010) and the Wellcome Tracker (Hamlyn et al., 2017). The mismatch between students valuing subjects and wanting or believing they can study them is illuminated by the concepts of ‘science capital’ and ‘self-efficacy’. Many students do not have high science capital, and their backgrounds mean that they therefore do not see themselves as studying science (and other STEM subjects) or pursuing careers involving STEM subjects. Low self-efficacy, or belief in ability to succeed, in what are perceived as hard subjects also contributes to the mismatch.

The study has two implications for teaching about human spaceflight in schools.

Firstly, the study does not suggest that providing young people with opportunities to learn about spaceflight and engage in spaceflight-related activities results in stimulating longer term interest in STEM subjects or in spaceflight or generates a desire to pursue careers in STEM subjects or in space science. However, as with STEM subjects, young people reported enjoying learning about space and space science was seen as important and bringing benefits to society.

The data point to many students perceiving STEM subjects as becoming increasingly difficult as they progress through school, with a requirement to be clever to study these subjects. This need to be clever is even more pronounced for space science. In tandem with the need to be clever is a lack of confidence in ability to study STEM subjects, and even less confidence in the ability to pursue careers in the space sector, a pattern of response that was particularly noticeable for girls. A further feature of the data was that students who did express interest in careers involving STEM subjects did not make connections between this and the possibility of that career being based in the *space* sector. A second implication of the study is that, as proposed by Reiss and Mujtaba (2017), careers education should be embedded in STEM lessons in order to expose young people to a wider range of materials on careers involving STEM subjects, include careers in space science.

This study focuses on reporting comparisons between data collected before the *Principia* mission (Phase 1 data) and data collected around one year after the mission (Phase 3, or delayed post-test data). In practice, there were comparatively few statistically significant differences when all phases were compared (i.e. Phase 1 to Phase 2, Phase 2 to Phase 3, and Phase 1 to Phase 3). This contrasts with other research into attitudes which suggest young people become less positive about school science as they progress through secondary education (e.g. Bennett & Hogarth, 2009). However, differences between participant groups and research instruments mean it is not possible to attribute this to the *Principia* mission.

The study findings on space science contrast with those of earlier work which do suggest that space is a motivating context for STEM subjects. Pell and Jarvis (2002 and 200) reported that interest in science was sustained in the months following engagement with space flight-related activities. This was not the case in the study reported here. What appears to be the case is that engaging in certain types of space-related activities generates temporary *situational interest*, i.e. students are interested in the specific activity in which they are participating as a result of features of their immediate situation. However, this does not have any enduring or long-lasting impact on personal desire to study STEM subjects and pursue careers in the space sector.

In summary, the findings point to influences wider than those in school having a substantial impact on subject and career choices in relation to STEM subjects and space science. The work on science capital (e.g. Archer and DeWitt, 2017), offers possible insights into why this might be the case: when young people choose a job or career, they need to feel that they will belong to a group where they will feel comfortable, confident and able to succeed. Currently, many young people do not feel this way about STEM subjects and space science and why they in the words of Jenkins and Nelson (2005), they see the subjects as “important but not for me”.

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1. Copies of the final instruments are available from the authors. [↑](#footnote-ref-2)